BODY WATER OF THE AMERICAN KESTREL

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Abstract

Body water mass was measured in 25 American Kestrels. I examined the potential of estimating body water mass from field measurements of wing chord length and body weight. Wing length was not a useful predictor of body water. The body water of kestrels collected in April, July, and September could be estimated with an accuracy of ± 4.0% by multiplying their body weights by 0.6104, 0.6455, and 0.6143, respectively. This method can be applied very easily in the field.

In one phase of a major study I investigated how accurately the weight of body water of American Kestrels (*Falco sparverius*) can be estimated from measures of body weight and wing length. The more comprehensive study was designed to measure the energy metabolism of kestrels in the field using the variables in the equation used to estimate CO_2 production based on turnover rates of D_2O and $H_2{}^{18}O$ (see LeFebrve 1964 and Mullen 1970 a and b and 1973). Body water is one of the variables in the equation used to estimate CO_2 production based on turnover rates of these heavy isotopes of water. The accuracy of such estimates of CO_2 production is closely tied to that of body water, e.g., a 5% error in estimating body water causes an error of the same magnitude in estimates of energy metabolism. I therefore began a search for the most accurate method of estimating body water that could be implemented in the field without sacrificing the bird.

The literature suggests that the fat-free body weight of a kestrel could be used to estimate its body water. Studies by Odum et al. (1964), Child (1969), Child and Marshall (1970), and Zimmerman (1965) have indicated that the ratio of body water to fat-free body weight in migrant birds is virtually a constant, little affected by the degree of fatness, stage of migration, sex, season, species, or wing length. On the other hand, Masher and Marcstrom (1976) reported a weak correlation between the ratio of water to fat-free body weight and wing length in Dunlins (*Caldris a. alpina*) during autumn migration.

Fat-free body weight cannot be measured without sacrificing the bird. Several investigators, however, have shown that fat-free body weight is highly correlated with wing length, an easy measurement to make in the field. But this method of estimating fat-free body weight should be used with some caution since the relationship between these two variables changes seasonally, e.g., Savannah Sparrow (*Passerculus sanwichensis*), Connell et al (1960); House Sparrow (*Passer domesticus bactrianus*), Dolnik (1970); Dunlin, Masher and Marcstrom (1976); and wood warblers (*Dendroica* sp.), Rogers and Odum (1964). Additionally, Moreau and Dolp (1970) and Snow and Snow (1963) found no or very weak correlations between wing length and fat-free dry weights in passerines.

In this study I examined the potentials for estimating the body water content of kestrels by two methods. The first involved estimating the fat-free body weight of an individual from its wing length and multiplying this value by the ratios of mean body water weight: fat-free body weight measured on a small sample of individuals in the population. In the second, the body weight of an individual was multiplied by the mean of the body water weight: body weight ratio which was based on a sampling of individuals in the population.

Methods

Sixteen male and nine female kestrels (23 adults, 2 immatures) were trapped in bal-chatri traps in Cache County, Utah, in April, July, September, and November of 1973 and 1974. Birds were transported to the laboratory at Utah State University, weighed to the nearest 0.1 g, and their wing chord lengths[1] measured to the nearest 1 mm. Each was then killed in an atmosphere of N_2, frozen, and stored. Later each carcass was vacuum dried for a minimum of 3 days to constant weight. To facilitate drying, the body cavity was opened, and the pectoral muscles were macerated. The weight of body water was considered equal to the body weight at capture minus the vacuum-dried weight. Each carcass was chopped into small pieces and the fat extracted in Soxhlet apparatus, using petroleum ether (B.P. 60–80°C) as the solvent, and dried to constant weight in a hot-air oven at 80°C. The weight of body fat was equated with the vacuum-dried weight minus the dry weight of the fat-extracted carcass (i.e., the fat-free dry weight). The fat-free body weight equals the weight of the bird just before death minus the weight of body fat. Student's test was used to compare any two means. Statistical significance was accepted at the 0.01 level of probability.

Results

Wing length and fat-free weight. Wing lengths of the kestrels were correlated with neither their fat-free body weight nor their fat-free dry weight. The correlation analysis was performed on the data grouped according to the month of capture and on the combined data for all individuals.

Body water: fat-free weight ratio. The body water: fat-free weight ratios for birds collected in April, July, September, and November averaged .6426, .6676, .6533, and .6412, respectively (table 1). The ratios for April and November were not significantly different ($P < .01$), but both differed significantly from the ratios in July and September. The ratio for birds captured in July differed significantly from that of those captured in September. There were no apparent differences in these ratios between the sexes for July, September, and November, but this conclusion is based on very small sample sizes collected in July and November. The sample size for April is also quite small, but the data suggest that the ratio differed between the sexes for that month.

Body water: body weight ratio. The ratio of body water to body weight was inversely related to weight of body fat in males and females (fig. 2). In females the ratio decreased from 0.66 to 0.55 as weight of body fat increased from 3 to 22 g. The relationship between body fat and the ratio of body water to body weight was not significantly ($P <$ .05) different between sexes. The body water: body weight ratios for kestrels collected in April, July, September, and November averaged .6100, .6455, .6142, and .5752.

Discussion

Body water: body weight ratio. The body water of the kestrels collected in April, July, and September could be estimated with an accuracy of ± 4.0% by multiplying their body weights by 0.6100, 0.6455, and 0.6142, respectively. This method can be

Table 1. Body weight, water, fat, and body water: fat-free weight ratios of American Kestrels collected in 4 different seasons.

Month of Collection	Sample	Mean Body weight (g)	S.E.	Mean Body water (g)	S.E.	Mean *Body water* Fat-free wt.	S.E.	Mean *Body water* Body weight	S.E.	Mean Body fat (g)	S.E.
April	4 ♂ ♂	98.2	2.31	59.8	1.25	.6365	.0041	.6090	.0077	4.29	1.12
	1 ♂	136.0		83.7		.6539		.6160		8.03	
						$\bar{x}$ = .6426	.0081	$\bar{x}$ = .6100	.0061		
July	3 ♂ ♂	103.4	2.20	66.4	1.29	.6636	.0031	.6426	.0014	3.38	0.52
	2 ♀ ♀	109.8	1.30	71.3	0.24	.6707	.0066	.6498	.0099	3.44	0.62
						$\bar{x}$ = .6676	.0046	$\bar{x}$ = .6455	.0037		
September	8 ♂ ♂	106.6	2.06	65.8	0.74	$\bar{x}$ = .6528	.0037	.6185	.0085	5.70	1.19
	5 ♀ ♀	119.1	3.86	72.2	1.77	$\bar{x}$ = .6520	.0042	.6073	.0099	8.33	2.01
						$\bar{x}$ = .6533	.0039	$\bar{x}$ = .6142	.0064		
November	1 ♂	96.6		58.7		.6385		.6074		4.69	
	1 ♀	145.1		78.8		.6426		.5430		22.48	
						$\bar{x}$ = .6412	.0099	$\bar{x}$ = .5752	.0322		

$\bar{x}$ = mean for both sexes

applied very easily in the field and is sufficiently accurate to be used with the $D_2{}^{18}O$ method to estimate the energy metabolism of a kestrel in the field.

Wing length and fat-free body weight. The lack of any correlation between wing length and fat-free body weight in a given season is somewhat puzzling. Individuals collected in September may have been migrants representing populations with different geographical origins, but this should not have been true in July. My results show that wing length cannot be used to predict fat-free weight of the American Kestrel and, therefore, cannot be used as a first step in estimating body water.

Body water: fat-free weight ratio. The water content of kestrels expressed as a fraction of fat-free weight is lower than that reported for passerines and shorebirds, which seem to be the only avian groups for which comparative values are available. The ratios of water: fat-free weight reported by Child (1969) for Swainson's Thrushes (*Hylocichla ustulata*) ranged from .6839 to .7029, while the mean values for 10 other small arboreal birds ranged from .6700 to .6967 (Child and Marshall 1970), leading them to suggest that in practice a water ratio of .6870 ± 0.011 could be used for other species of adult migrant birds ranging in size from the Yellow-billed Cuckoo (*Coccyzus americanus*) to small warblers (*Dendroica* sp.). I computed the water content for Dickcissels *Spiza americana*) collected in winter, during migration and during the breeding season from the data in Zimmerman (1965). The mean values ranged from .6774 to .7086 and did not vary seasonally. The water content of Dunlins ranged from .66 to .71 (Mascher and Marcstrom 1976).

In contrast, the mean ratios of water: fat-free weight of kestrels in this study ranged seasonally from .6412 to .6676. These values are significantly lower and do not overlap with those cited above for passerines and shore birds. Data on the water content of other species are not available, and the question of whether these low values are characteristic of Falconiformes, or raptors in general, can be resolved only by future investigations.

The seasonal changes in the water content of the kestrel resemble the pattern in Chaffinches (*Fringilla c. coelebs*) (Gavrilov and Dolnik 1974). The highest water content of the year in Chaffinches is reached in July, following the breeding season, while body fat is at its lowest level.

Summary

1. Body water: body weight ratio and wing length were evaluated as independent predictors of the body water of the kestrel.

The body water of kestrels collected in April, July, and September could be estimated with an accuracy of ± 4.0% by multiplying their body weights by the body water: body weight ratios 0.6104, 0.6455, and 0.6143, respectively. This method can be applied very easily in the field.

Wing length of kestrels was not correlated with fat-free body weights, body mass, or body water.

2. Body water: body weight ratios in kestrels ranged from 0.65 to 0.55.

In both males and females the ratio was inversely and nonlinearly related to body fat values that ranged from 3 to 11 g. In the range of 11 to 22 g of body fat, the relationship appears to be linear. The latter data are for females only.

3. Mean water content of kestrels expressed as a fraction of fat-free body weight ranged seasonally from 0.6142 to 0.6612 but was relatively constant within a season ir-

respective of sex, size, or fat accumulation. The water-content values were significantly lower than those reported for passserines and shorebirds.

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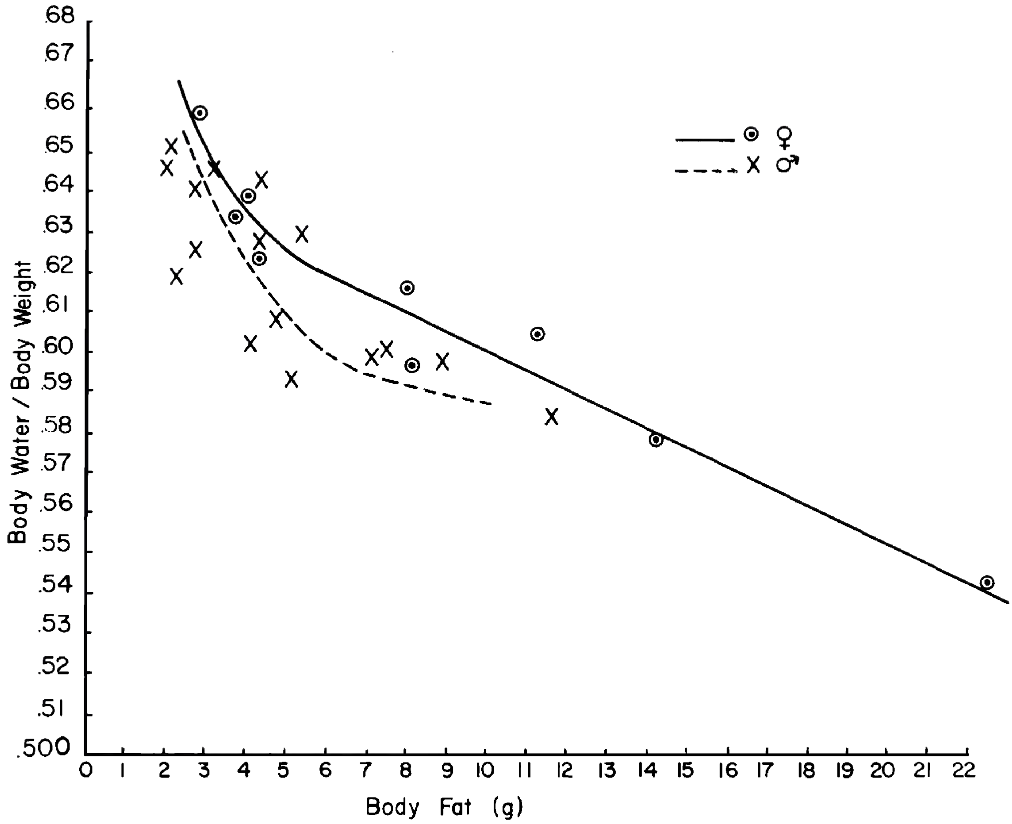

Figure 1.—The relationship between body fat and the body water: body weight ratios of kestrels.